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Publication date:
1981

Document Version
Publisher's PDF, also known as Version of record

Risø-R-448

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Risø-R-448

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A. Aarkrog, J. Lippert, and H. Dahlgaard

Risø National Laboratory, DK-4000 Roskilde, Denmark
July 1981

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ENVIRONMENTAL RADIOACTIVITY IN THE FAROES IN 1980

A. Aarkrog, J. Lippert, and H. Dahlgaard

Abstract. Measurements of fallout radioactivity in the Faroes in 1980 are presented. Strontium-90 (and ^{137}Cs in most cases) was determined in regularly collected samples of precipitation, grass, milk, fish, sea water, bread and drinking water. In addition, analyses were made of spot samples of lamb, sea birds, potatoes, sea plants, vegetables, eggs, and human bone. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in the human diet in the Faroes in 1980.

INIS Descriptors

[0] DIET, ENVIRONMENT, EXPERIMENTAL DATA, FAROE ISLANDS, FISHES, FOOD, FOOD CHAINS, GLOBAL FALLOUT, GRAPHS, MILK, PLANTS, RADIOACTIVITY, SEA WATER, SHEEP, TABLES

[1] ATMOSPHERIC PRECIPITATIONS, BONE TISSUES, DRINKING WATER, MAN, STRONTIUM 90

[2] CESIUM 137

UDC 614.73 (491.2)

July 1981

Risø National Laboratory, DK-4000 Roskilde, Denmark

ISBN 87-550-0778-3
ISSN 0106-2840

Risø Repro 1981

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ABBREVIATIONS AND UNITS

J: joule: the unit of energy; 1 J = 1 Nm (= 0.239 cal)
Gy: gray: the unit of absorbed dose = 1 J kg^{-1} (= 100 rad)
Sv: sievert: the unit of dose equivalent = 1 J kg^{-1} (= 100 rem)
Bq: becquerel: the unit of radioactivity = 1 s^{-1} (= 27 pCi)

cal: calorie = 4.186 J
rad: 0.01 Gy
rem: 0.01 Sv
Ci: curie: $3.7 \cdot 10^{10}$ Bq (= $2.22 \cdot 10^{10}$ dpm)

T: tera: 10^{12}
G: giga: 10^{9}
M: mega: 10^{6}
m: milli: 10^{-3}
μ: mikro: 10^{-6}
n: nano: 10^{-9}
p: pico: 10^{-12}
f: femto: 10^{-15}
a: atto: 10^{-18}

cap: caput: (per individual)
TNT: trinitrotoluol; 1 Mt TNT: nuclear explosives equivalent to 10^{9} kg TNT.

cpm: counts per minute
dpm: disintegrations per minute
OR: observed ratio
CF: concentration factor
FP: fission products
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$

V: vertebrae

m: male

f: female

nSr: natural (stable) Sr

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl (~ 0.88 dpm)

S.D.: standard deviation: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{(n-1)}}$

S.E.: standard error: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{n(n-1)}}$

U.C.L.: upper control level

L.C.L.: lower control level

S.S.D.: sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$

f: degrees of freedom

s^2: variance

v^2: ratio between the variance in question and the residual variance

P: probability fractile of the distribution in question

η: coefficient of variation, relative standard deviation

ANOVA: analysis of variance

A: relative standard deviation 20-33%

B: relative standard deviation >33%, such results are not considered significantly different from zero activity

B.D.L.: below detection limit

In the significance test the following symbols were used:

* : probably significant (P > 95%)

** : significant (P > 99%)

***: highly significant (P > 99.9%)

1. INTRODUCTION

1.1.

The fallout programme for the Faroes, which was initiated in 1962[1] in close co-operation with the National Health Service and the chief physician of the Faroes, was continued in 1980. Samples of human bone were obtained in 1980 from Dronning Alexandrine's Hospital in Thorshavn.

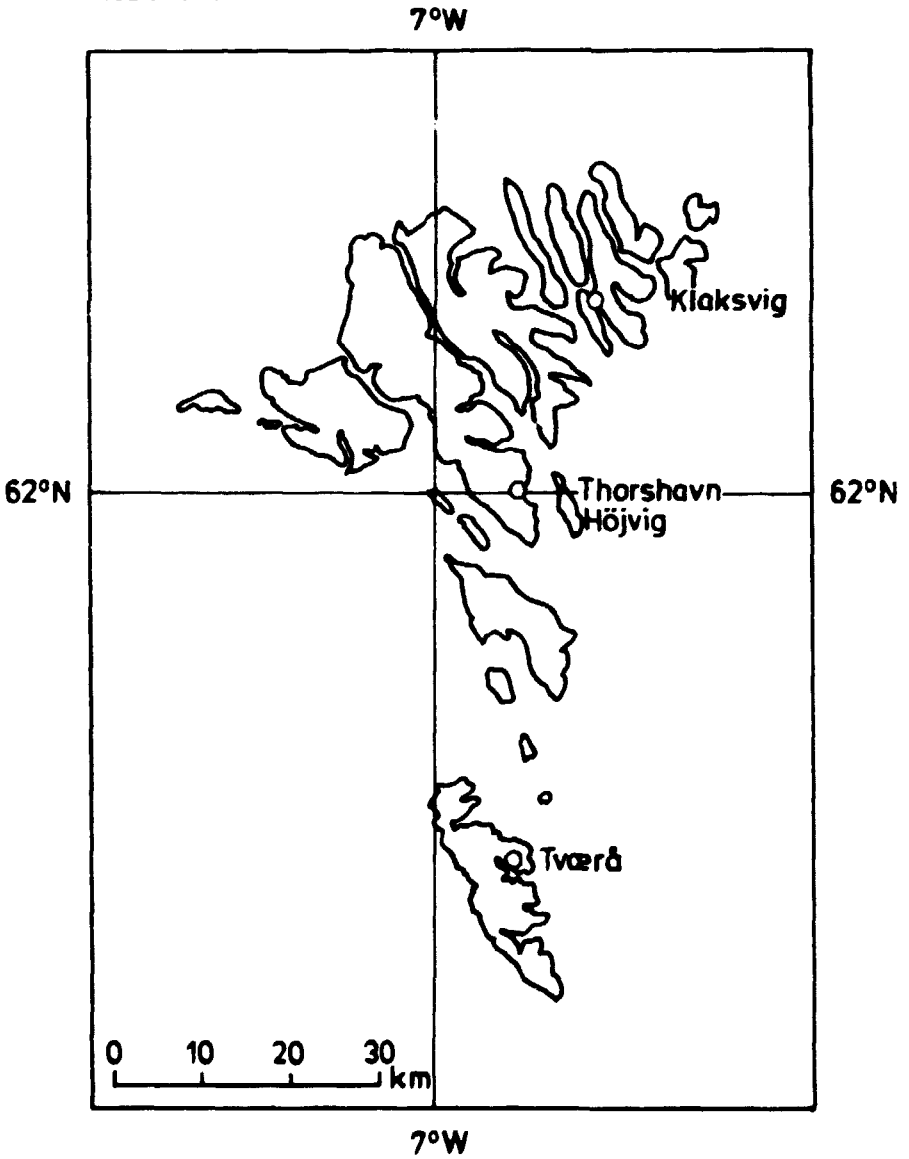

Fig. 1. The Faroese Islands.

1.2.

The present report will not repeat information concerning sample collection and analysis already given in Risø Reports Nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 266, 292, 306, 324, 346, 361, 387, 404 and 422[1].

1.3.

The estimated mean diet of the Faroese as used in this report is still based on the estimate given by Professor E. Hoff.Jørgensen, Ph.D., in 1962.

1.4.

The present investigation was carried out together with corresponding examinations of fallout levels in Denmark and Greenland, described in Risø Reports Nos. 477[2] and 479[3], respectively.

2. RESULTS AND DISCUSSION

2.1. Strontium-90 in precipitation

Table 2.1 shows the ^{90}Sr content in precipitation collected at Højvig (near Thorshavn) and Klaksvig in 1980. The amount of fall-out at Klaksvig was a factor of 1.1 greater than that found at Højvig.

The ^{90}Sr fallout in 1980 was approximately 0.7 times of the 1979 levels in the Faroes. In Denmark the 1980 levels were also 0.7 times the 1979 levels[2].

Table 2.1. Strontium-90 in precipitation in the Faroes in 1980

	Höjvig		Klaksvig	
	Bq m^{-3}	Bq m^{-2}	Bq m^{-3}	Bq m^{-2}
Jan	9.3 A	0.86 A	7.7 A	2.3 A
Feb	3.0 B	0.160 B	6.8 B	0.37 B
March	12.6	1.20	7.0	1.16
April	8.2	0.45	6.4	1.21
May	10.3 B	0.177 B	7.4	0.37
June	10.9 A	4.6 A	5.7	0.68
July	8.4	0.99	7.8	0.91
Aug	(3.5)	(0.34)	3.0	0.46
Sept	4.0 A	0.50	2.8	0.78
Oct	2.8	0.72	2.2	0.63
Nov	(2.8)	(0.41)	2.4	0.55
Dec	7.1	1.27	11.3 B	3.2 B
1980	9.1	Σ 11.7 Σ_m 1.291	5.7	Σ 12.6 Σ_m 2.227
1980	0.25 pCi l^{-1}	Σ 0.32 mCi km^{-2}	0.154 pCi l^{-1}	Σ 0.34 mCi km^{-2}

Figures in brackets calculated from VAR3[12].

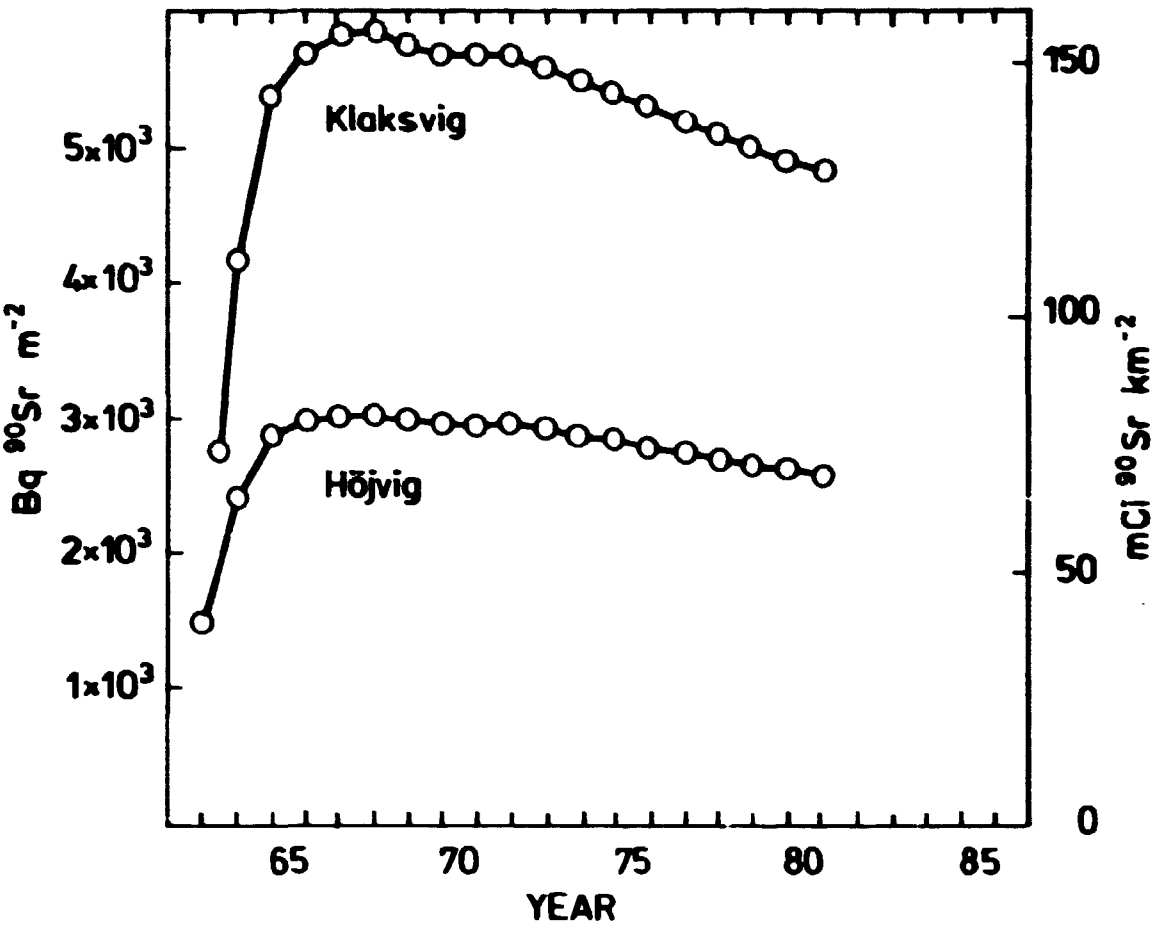

Fig. 2.1. Accumulated ^{90}Sr at Klaksvig and Højvig calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish fallout data (cf. Risø Report No. 403[2], Appendix D) and from the ratio between the ^{90}Sr fallout at the Faroese stations and the fallout in Denmark in the period 1962-1974.

2.2. Strontium-90 and Cesium-137 in grass

Grass samples were collected near Thorshavn in 1980. Table 2.2 shows the results. The 1980 ^{137}Cs level in grass was 0.6 times the 1979 level. As compared with Danish grass in 1980[2] we found the ^{90}Sr level in the Faroese grass to be higher by a factor of approximately 5 in the summer months.

Table 2.2. Strontium-90 and Cesium-137 in grass from Thorshavn 1980

Month	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$^{137}Cs/^{90}Sr$
June	2.08	3900	7.9	1290	3.8
August	1.53	5900	4.9	1290	3.2

2.3. Strontium-90 and Cesium-137 in milk

As in previous years[1], weekly samples of fresh milk were obtained from Thorshavn, Klaksvig, and Tverå. Strontium-90 and ^{137}Cs were determined in bulked monthly samples.

Table 2.3.1 shows the results and Tables 2.3.2, 2.3.3 and 2.3.4 the analysis of variance of the S.U., M.U., and pCi ^{137}Cs l^{-1} figures respectively. As also observed in previous years, the variation between locations was significant for ^{137}Cs as well as for ^{90}Sr. The highest levels were found in the milk from Tverå.

Figure 2.3.1 shows the quarterly Bq ^{90}Sr (kg Ca)$^{-1}$ values and Fig. 2.3.2 the quarterly Bq ^{137}Cs m^{-3} levels since 1962. The annual mean values for 1980 were 280 Bq ^{90}Sr (kg Ca)$^{-1}$ (7.7 S.U.) and 4300 Bq ^{137}Cs m^{-3} (117 pCi ^{137}Cs l^{-1}), i.e. the ^{90}Sr levels in 1980 were 93% of the 1979 concentration, while the ^{137}Cs levels were approximately 80% of the 1979 mean levels. In Danish milk the ^{90}Sr concentration did not change from 1979 to 1980, but the ^{137}Cs 1980 level was 60% of the 1979 content.

The annual mean values of the ratio: Bq ^{137}Cs (kg K)$^{-1}$/Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk are shown in Fig. 2.3.3. The mean ratio in 1980 for the three locations was 9.7±1.1 (1 S.E.) during the grazing period (May-October), and in the winter time it was 8.8± 1.3.

Figure 2.3.4 shows a comparison between the ^{90}Sr and ^{137}Cs levels in Faroese- and Danish-produced milk. It is evident that indirect contamination plays an important role for the ^{137}Cs levels in the Faroes, because the ratio between ^{137}Cs in Faroese and Danish milk increases when the fallout rate decreases. The ratios between the ^{90}Sr levels in Faroese and Danish milk have shown a slight tendency to decrease through the years.

An ANOVA of the potassium content in Faroese milk collected since 1964 showed no significant difference between the 3 locations. The variation in time was significant. The mean value was 1.69 g K l^{-1}. The relative standard deviation was 9%.

Table 2.3.1. Strontium-90 and Cesium-137 in milk from the Faroes in 1980

	Thorshavn			Klaksvig			Tværå			Mean		
Month	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$
Jan	250	1590	890	250	4100	2300	380	4300	2400	290	3300	1850
Feb	200	1930	1110	380	4100	2200	270	3500	2000	280	3200	1780
March	260±30	2100	1180	260	4300	2400	270	3600	2100	260	3300	1880
April	230	2100	1220	240	3300	1670	330	5900	3100	270	3800	2000
May	195	1960	1080	280	3000	1600	410	5200	2700	300	3400	1800
June	250	2200	1350	260	2900	1620	340	5800	3400	280	3700	2100
July	290	4300	3100	191	3400	1980	360	7300	4800	280	5000	3300
Aug	340	5500	3500	330	5500	3100	390	8000	4800	350	6300	3800
Sept	290	4400	2700	380	5000	3100	350	5500	3500	340	5000	3100
Oct	210	3000	1930	280	5100	3300	270	7100	4300	250	5100	3200
Nov	185	1950	1200	350	6400	4100	260	6100	3600	260	4800	3000
Dec	191	2300	1410	230	6500	4100	290	7100	4300	240	5300	3300
Mean	240	2800	1720	290	4500	2600	330	5800	3400	280	4300	2600
Mean (pCi)	6.5 S.U.	75 pCi ^{137}Cs l^{-1}	47 M.U.	7.8 S.U.	120 pCi ^{137}Cs l^{-1}	71 M.U.	8.8 S.U.	156 pCi ^{137}Cs l^{-1}	92 M.U.	7.7 S.U.	117 pCi ^{137}Cs l^{-1}	70 M.U.

Table 2.3.2. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Farcese milk in 1980 (from Table 2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	0.448	11	0.041	1.201	-
Between locations	0.573	2	0.287	8.440	> 99.5%
Remainder	0.747	22	0.034		

Table 2.3.3. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1980 (from Table 2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	3.171	11	0.288	3.655	> 99.5%
Between locations	3.697	2	1.848	23.431	> 99.95%
Remainder	1.735	22	0.079		

Table 2.3.4. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1980 (from Table 2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	2.124	11	0.193	2.885	> 97.5%
Between locations	4.087	2	2.044	30.535	> 99.95%
Remainder	1.473	22	0.067		

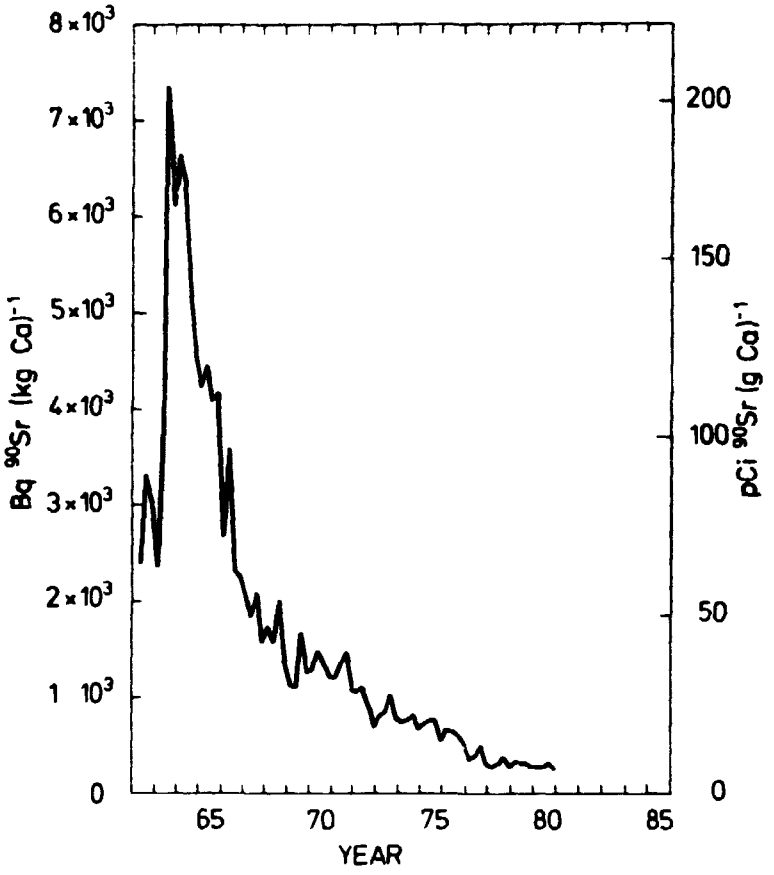

Fig. 2.3.1. Strontium-90 in Faroese milk, 1962-1980.

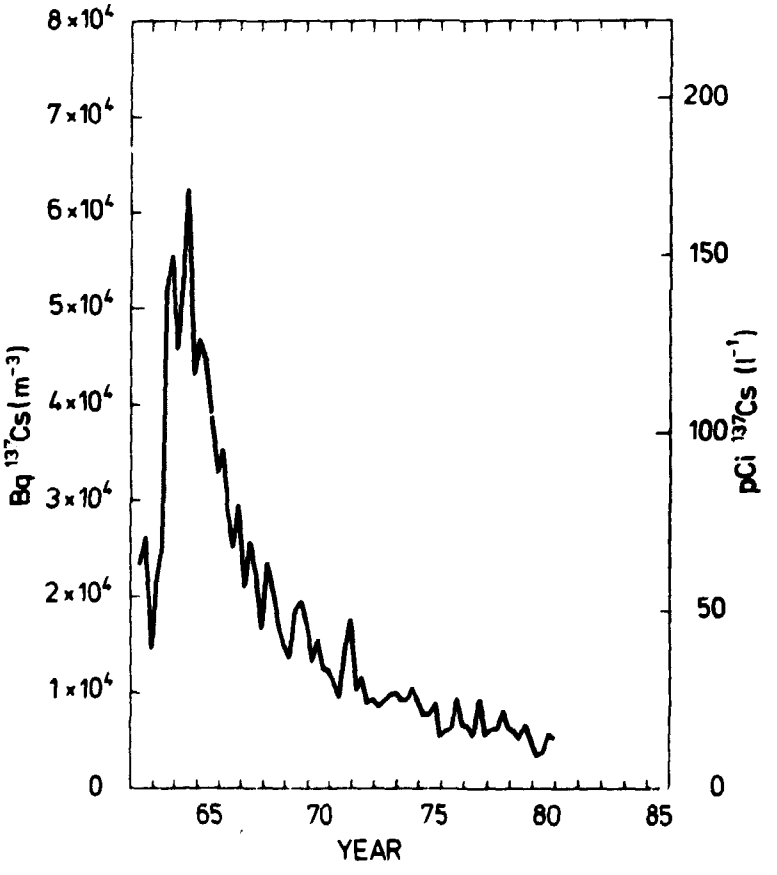

Fig. 2.3.2. Cesium-137 in Faroese milk, 1962-1980.

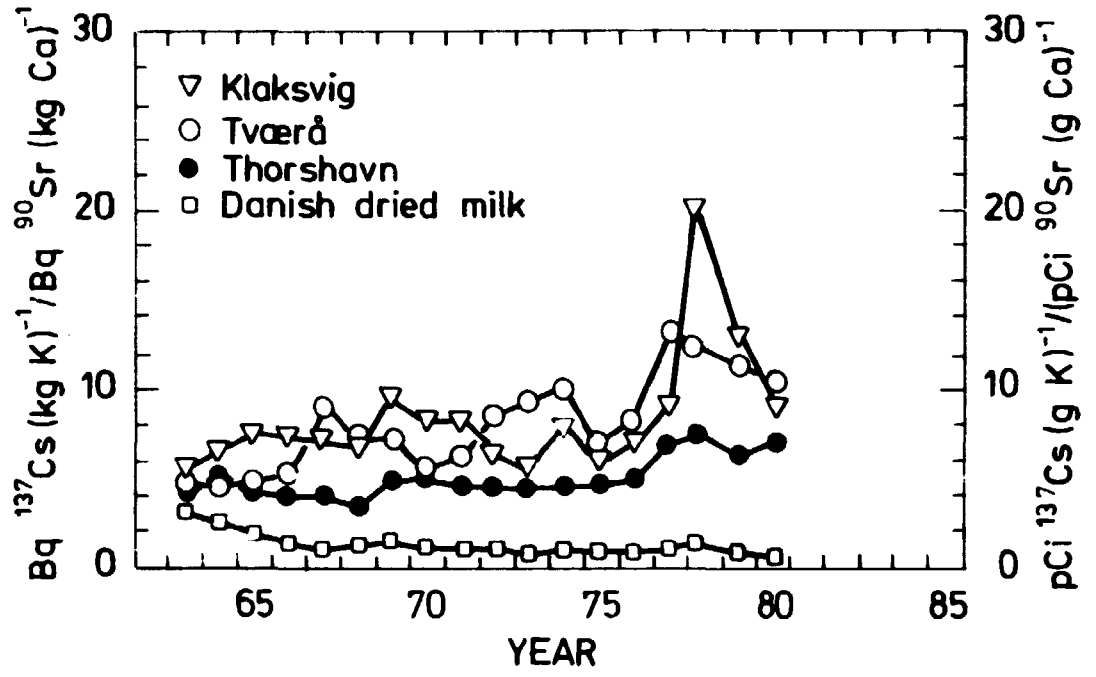

Fig. 2.3.3. $\frac{\text{M.U.}}{\text{S.U.}}$ ratios in Faroese and Danish milk, 1963-1980.

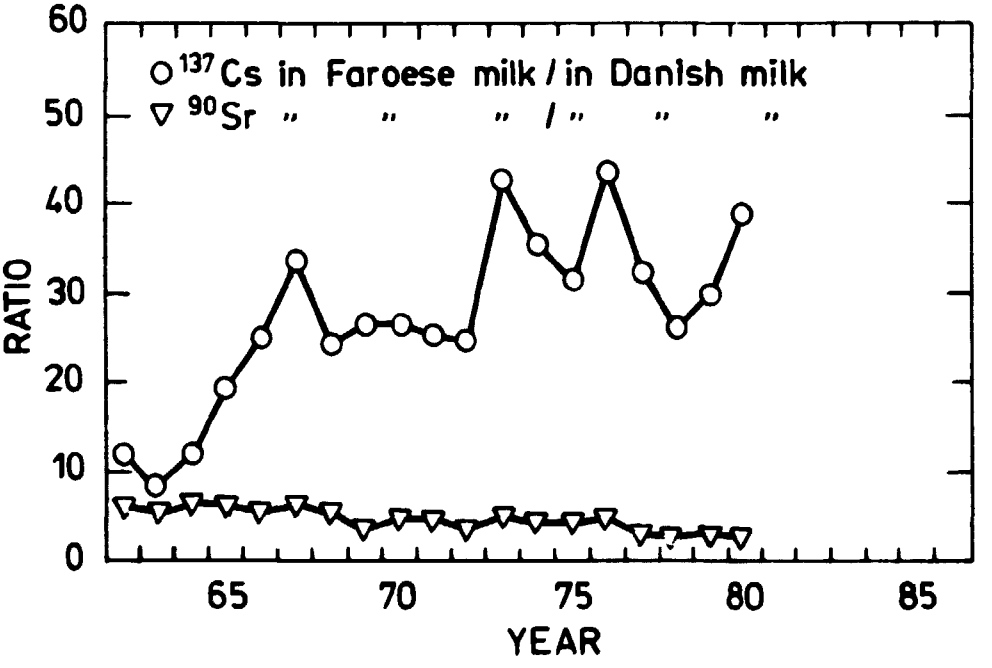

Fig. 2.3.4. A comparison between Faroese and Danish milk levels, 1962-1980.

2.4. Strontium-90 and Cesium-137 in terrestrial animals

The 1980 mean levels in two samples of mutton (Table 2.4.1) were 0.22 Bq ^{90}Sr kg^{-1} and 48 Bq ^{137}Cs kg^{-1}. The mean bone level was 2500 Bq ^{90}Sr $(kg\ Ca)^{-1}$.

Table 2.4.1. Strontium-90 and Cesium-137 in Faroese mutton collected in 1980

Location	Date	Sample	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$
Tværå	Oct	Meat	0.31	3040	93	35000
		Bone	-	3900	-	-
Streymoy	Dec	Meat	0.13	1430	2.8	1080
		Bone	-	1040	-	-

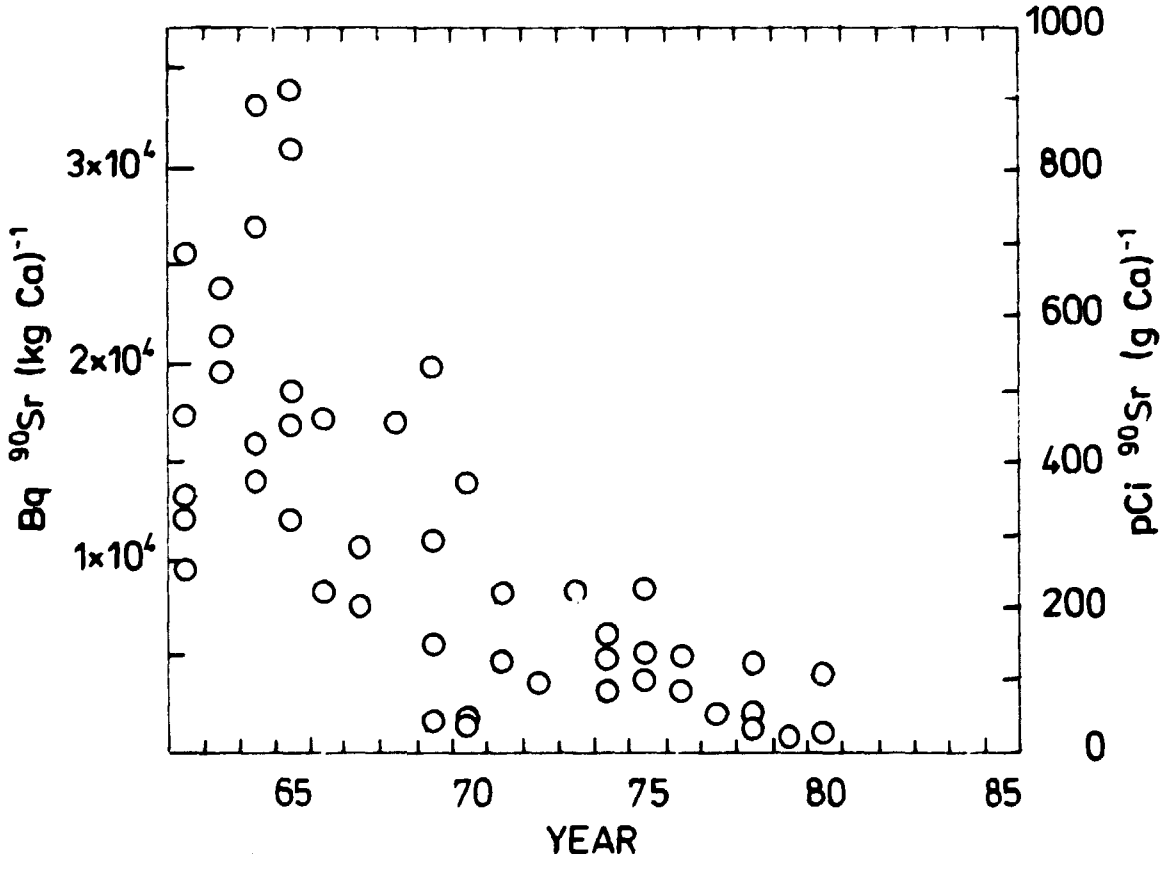

Fig. 2.4.1. Strontium-90 (Bq $(kg\ Ca)^{-1}$) in lamb bone collected in the Faroes, 1962-1980.

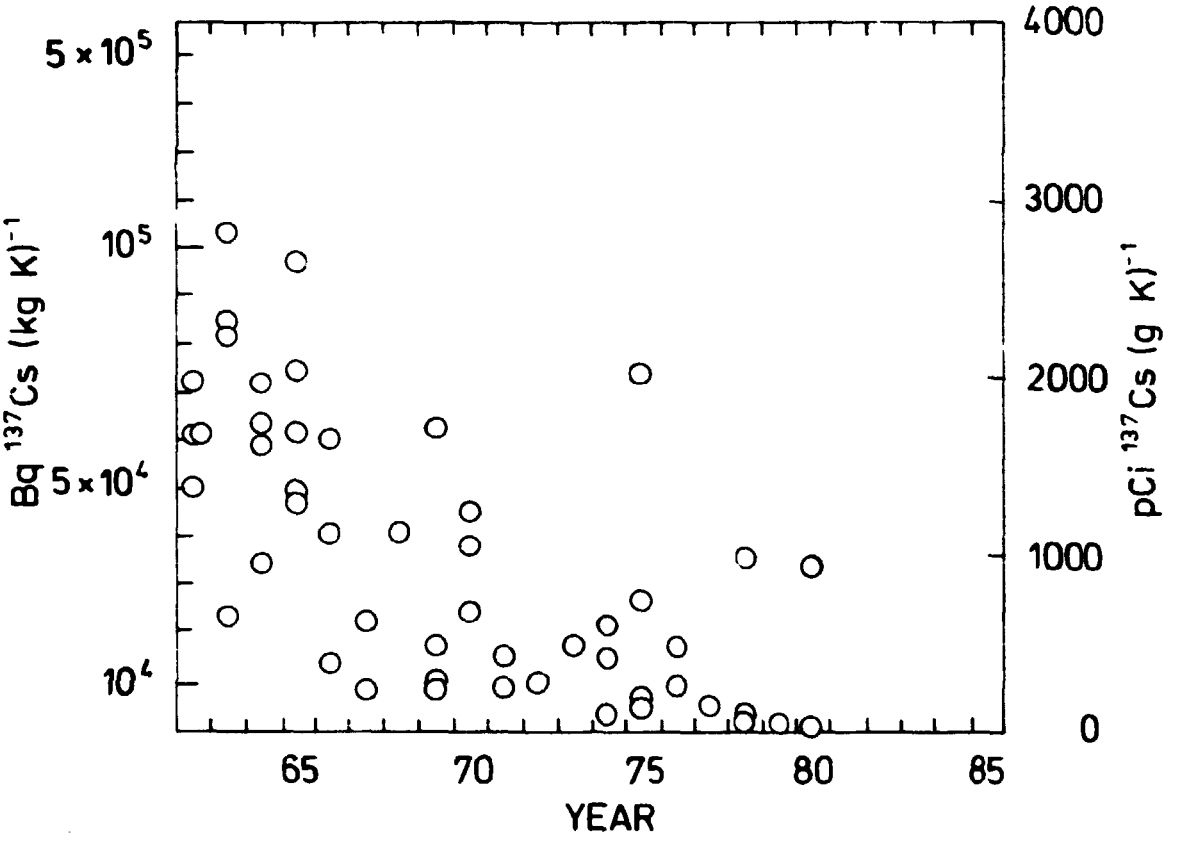

Fig. 2.4.2. Cesium-137 (Bq (kg K)$^{-1}$) in lamb meat collected in the Faroes, 1962-1980.

2.5. Strontium-90 and Cesium-137 in sea animals

Table 2.5.1 shows the ^{137}Cs levels in fish collected in 1980 in the Faroes. The mean levels in Gadus aeglefinus and Gadus callarias were 0.27 Bq ^{137}Cs kg^{-1} and 0.0135 Bq ^{90}Sr kg^{-1}.

Table 2.5.1. Strontium-90 and Cesium-137 in sea animals from the Faroes in 1980

Sampling month	Species	Sample type	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (g K)$^{-1}$
Feb	Gadus callarias	Cod flesh	0.0054	38	0.20	60
April	- " -	- " -	0.0048	54	0.38	110
June	- " -	- " -	0.0057	69	0.39	115
Sept	- " -	- " -	0.0312	250	0.23	78
Nov	- " -	- " -	0.0134	120	0.28	80
Feb	Gadus aeglefinus	Haddock flesh	0.0140	97	0.28	100
April	- " -	- " -	0.0079	57	0.20	67
June	- " -	- " -	0.0061	57	0.22	67
Sept	- " -	- " -	0.0282	360	0.26	88
Nov	- " -	- " -	0.0180	170	0.26	89
Oct	Grind whale	Meat	0.041	850	0.19	59

Grind contained 0.19 Bq ^{137}Cs kg^{-1} and 0.041 Bq ^{90}Sr kg^{-1}.

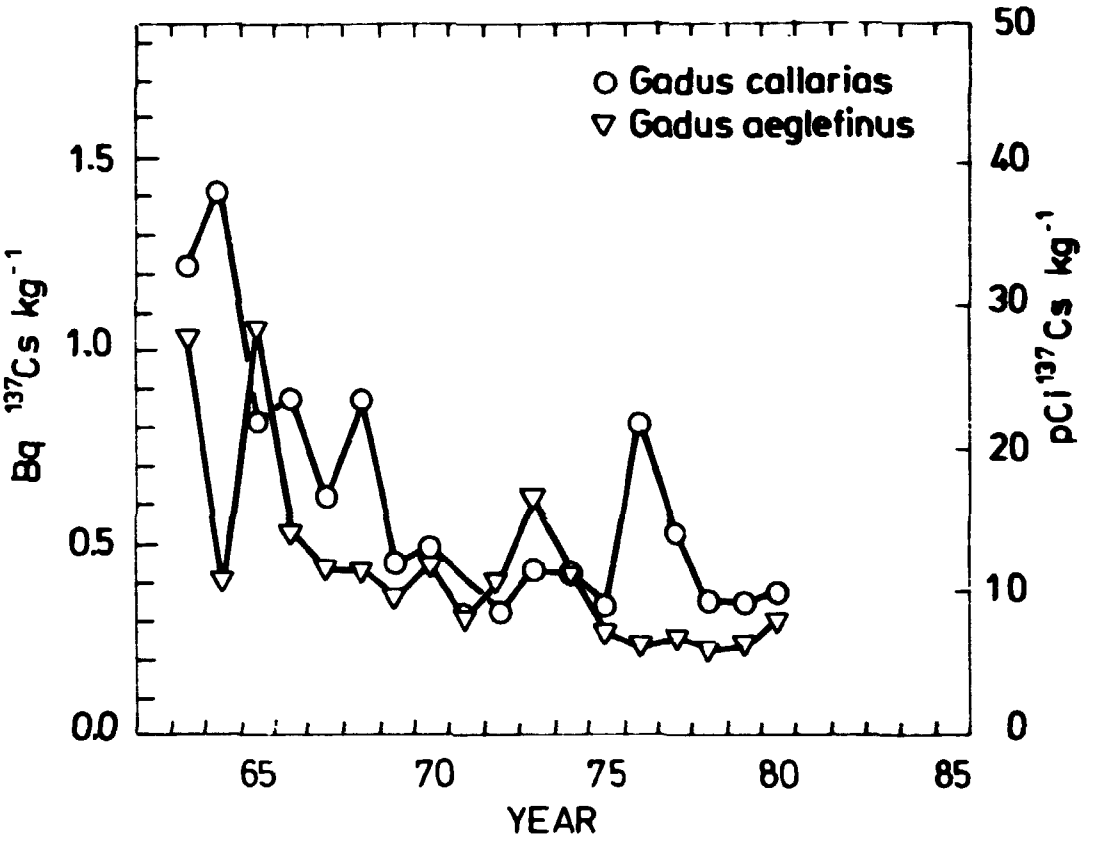

Fig. 2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and Haddock (Gadus aeglefinus) collected in the Faroes, 1962-1980).

2.6. Strontium-90 in drinking water

Drinking-water samples were collected as previously but the samples were combined before the analysis as shown in Table 2.6.1. As in previous years, drinking water from Thorshavn contained more ^{90}Sr than that from Tværå (cf. the explanation in Risø Report No. 181[1]). The mean level in 1980 was 5.3 Bq ^{90}Sr m^{-3} (0.14 pCi l^{-1}), i.e. a little lower than in 1979.

Table 2.6.1. Strontium-90 in drinking water from the Faroes in 1980 (Unit: Bq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-June	10.4	2.6	5.8
July-Sept	8.2	1.47	3.5
1980	9.3	2.0	4.6

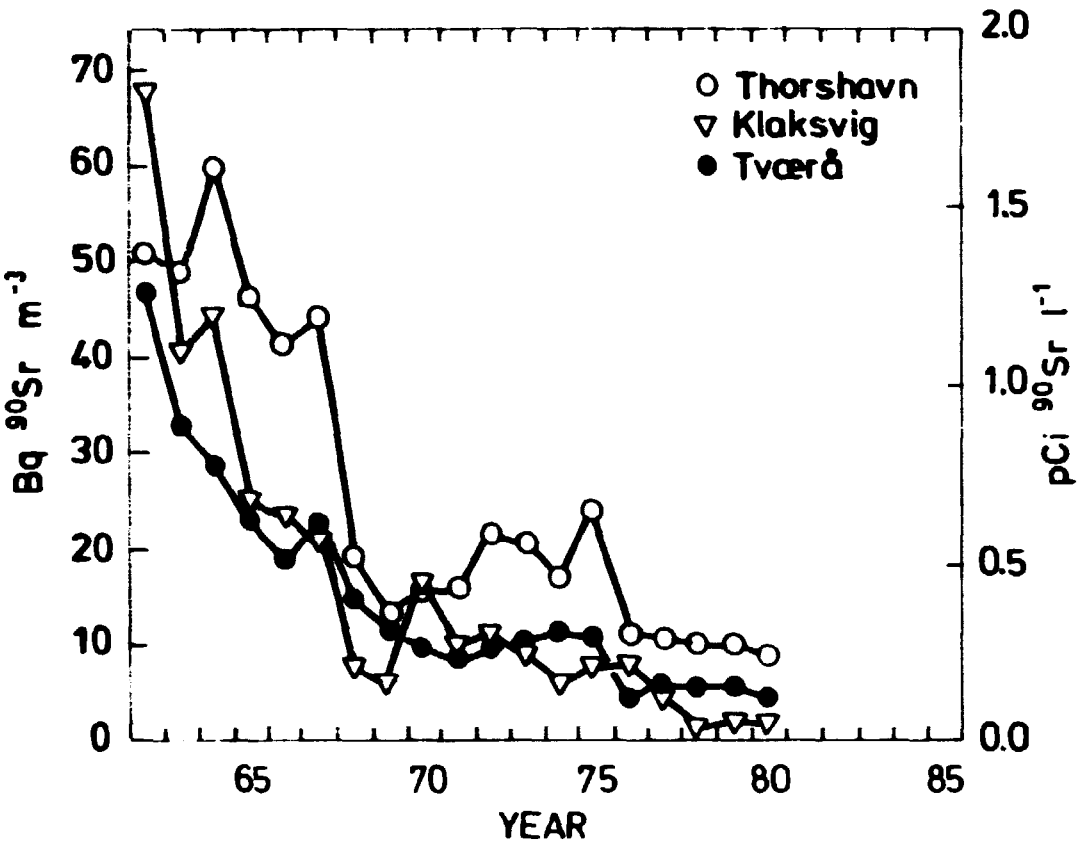

Fig. 2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1980.

Figure 2.6.1 shows the annual mean levels of ^{90}Sr in drinking water from the three locations since 1962.

The tritium concentrations in Faroese drinking water (Table 2.6.2) did not follow the ^{90}Sr levels. The drinking water from Thorshavn thus did not contain more tritium than at the other locations.

Table 2.6.2. Tritium in drinking water from the Faroes in 1980. (Unit: kBq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-March	2.0±0.18	3.1±0.18	10.0±1.11
July-Nov	5.9±0.37	5.7±0.56	6.1±0.56

2.7. Strontium-90 and Cesium-137 in miscellaneous samples

2.7.1. Soil

No soil samples were collected in 1980 from the Faroes. From earlier years' observations we estimate the accumulated fallout at Thorshavn to be 2580 Bq ^{90}Sr m^{-2} and that at Klaksvig to be 4800 Bq ^{90}Sr m^{-2} (cf. Fig. 2.1).

2.7.2. Sea water

Surface sea water was collected near Thorshavn on two occasions in 1980. The ^{90}Sr mean level was 2.3 Bq ^{90}Sr m^{-3} and 3.5 Bq ^{137}Cs m^{-3}.

Table 2.7.2.1. Strontium-90 and Cesium-137 in surface sea water from the Faroes in 1980

Sampling month	Bq ^{90}Sr m^{-3}	Bq ^{137}Cs m^{-3}	Salinity o/oo
March	-	3.6	36.9
Aug	2.3	3.4	35.2

Figure 2.7.2 shows the ^{90}Sr levels since 1962.

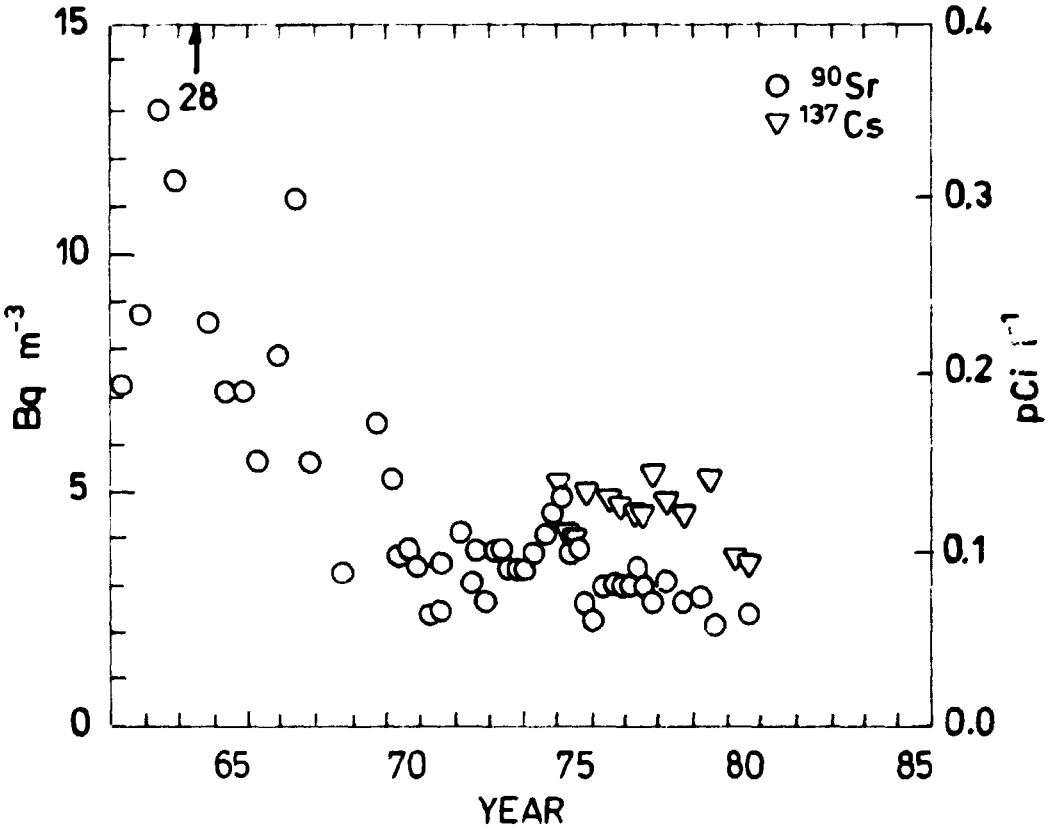

Fig. 2.7.2. Strontium-90 and Cesium-137 in Faroese sea water, 1962-1980. The ^{137}Cs data were revised after a remeasurement of all old samples.

The $^{137}Cs/^{90}Sr$ ratio was 1.5, i.e. as expected in ocean water.

Six samples from 1975 and 1976 were remeasured for ^{137}Cs. Figure 2.7.2 shows the results. The high $^{137}Cs/^{90}Sr$ ratios in especially 1977 still suggest a contribution of radiocesium from Windscale.

Tritium was measured in Faroese sea water collected in 1979 and 1980 (Table 2.7.2.2). From measurements of tritium in Danish waters in 1979 (72 samples) and in 1980 (57 samples) (cf. Risø-R-421 and Risø-R-447[1]), the following regressions were found:

Table 2.7.2.2. Tritium in surface sea water from the Faroes in 1979 and 1980

Month	Year	kBq ^{3}H m^{-3} ±1 S.E.	Calculated (cf. text)	Salinity o/oo
August	1979	1.7±0.32	1.7	36.9
March	1980	4.6±0.56	3.1	36.9
August	1980	4.1±0.37	3.5	35.2
September*	1980	4.4±0.37	6.1	25.2

*Norway

The error term is 1 S.E. of the mean of double determinations.

1979: kBq ^{3}H m^{-3} = 10.6 - 0.24 × salinity in o/oo

1980: kBq ^{3}H m^{-3} = 12.7 - 0.26 × salinity in o/oo.

If these two equations are used for an estimate of the tritium concentrations in sea water collected in the North Atlantic Ocean in 1979 and 1980, we get the results shown as calculated data in Table 2.7.2.2. It appears that there was no significant difference between measured and calculated tritium concentrations.

2.7.3. Sea plants

One sample of Laminaria was analysed in 1980. It contained 0.20 Bq ^{90}Sr kg^{-1} (59 Bq ^{90}Sr (kg Ca)$^{-1}$ and 0.16 Bq ^{137}Cs kg^{-1} (16 Bq ^{137}Cs (kg K)$^{-1}$).

As compared with Danish fucoids in 1980[2] the Faroese ^{137}Cs level was 14 times lower. If we assume the same concentration factors

between fucoids and sea water at the Faroes as in Danish waters, we may assume that the Faroese sea water contained 14 times less ^{137}Cs than the Danish, which (at the fucoid locations) contained 0.031±0.010 (1 S.D.) Bq ^{137}Cs l^{-1}. Hence the predicted ^{137}Cs level in Faroese water was 0.0023±0.0007 Bq ^{137}Cs l^{-1}, and we measured 0.0035. Hence the observed level was higher than the calculated. This was also the case in 1979. We may therefore conclude that the concentration factor for Laminaria in Faroese waters may be lower than that of Fucus in Danish waters.

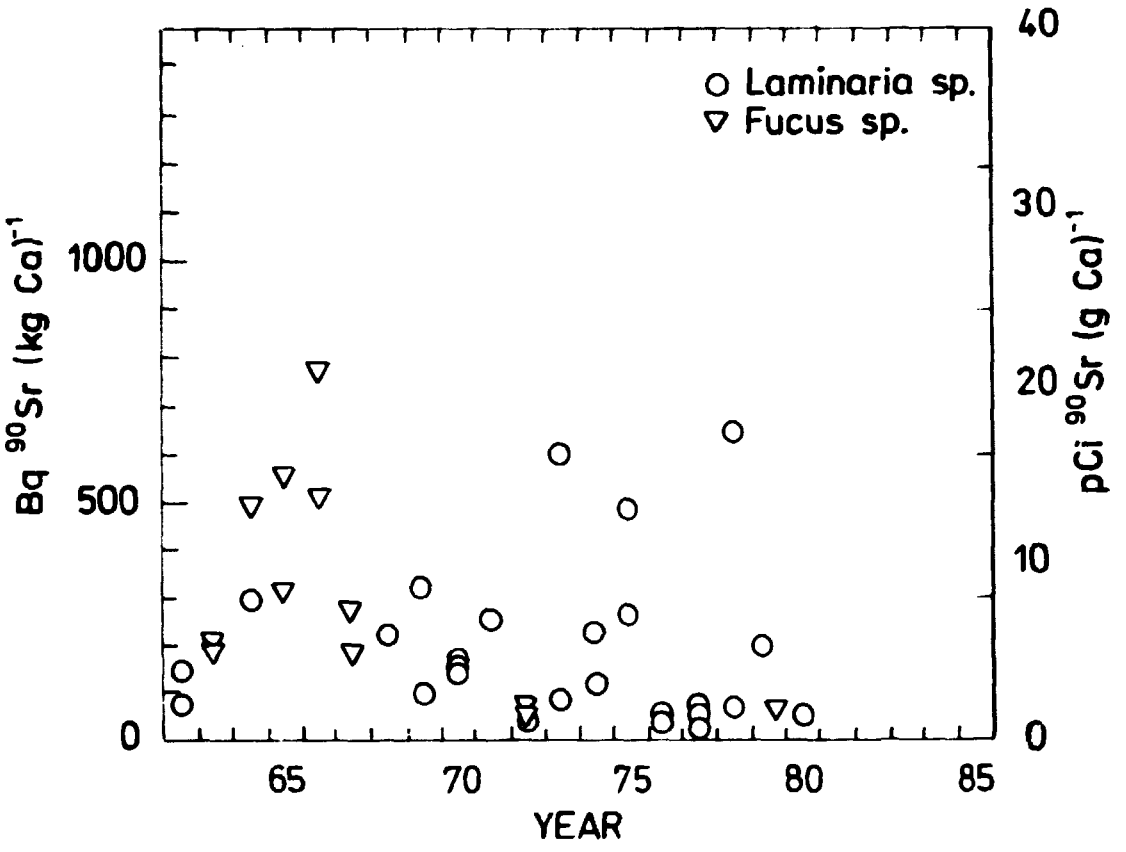

Fig. 2.7.3. Strontium-90 (Bq (kg Ca)$^{-1}$) in sea plants collected at Thorshavn, 1962-1980.

2.7.4. Vegetables

Table 2.7.4 shows the results of the ^{90}Sr and ^{137}Cs determinations.

Table 2.7.4. Strontium-90 and Cesium-137 in potatoes and vegetables from the Faroes in 1980

Location	Month	Sample	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
Klaksvig	Sept	Potatoes	0.21	8700	4.11	1090
Tværå	Oct	- " -	0.095	4900	4.91	1400
Strøme	Dec	- " -	-	-	1.61	420
	Aug	Cauliflower	0.26	2200	0.76	270
	"	Carrots	0.27	1150	0.21	70

The ^{137}Cs mean level in potatoes: 3.54 Bq kg^{-1} (96 pCi kg^{-1}) was higher than that observed in 1979, and the ^{90}Sr level: 0.15 Bq kg^{-1} (4.1 pCi kg^{-1}) was lower. The ^{90}Sr level in carrots was half the Danish level[2] while the ^{137}Cs level was 4 times higher in the Faroes produce.

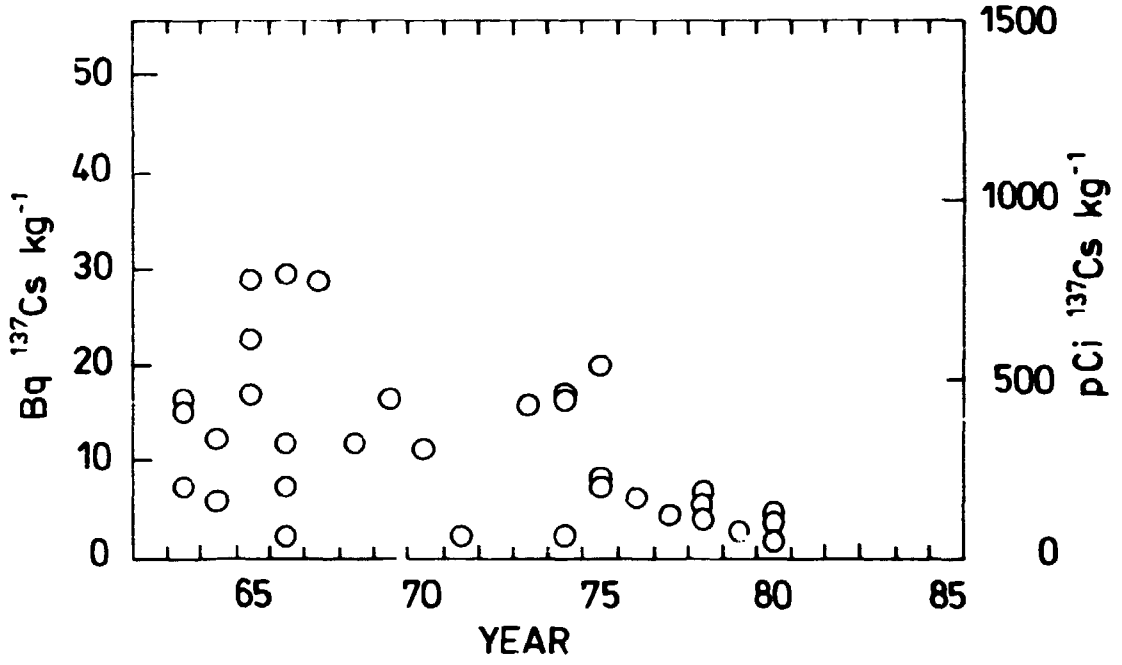

Fig. 2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1980.

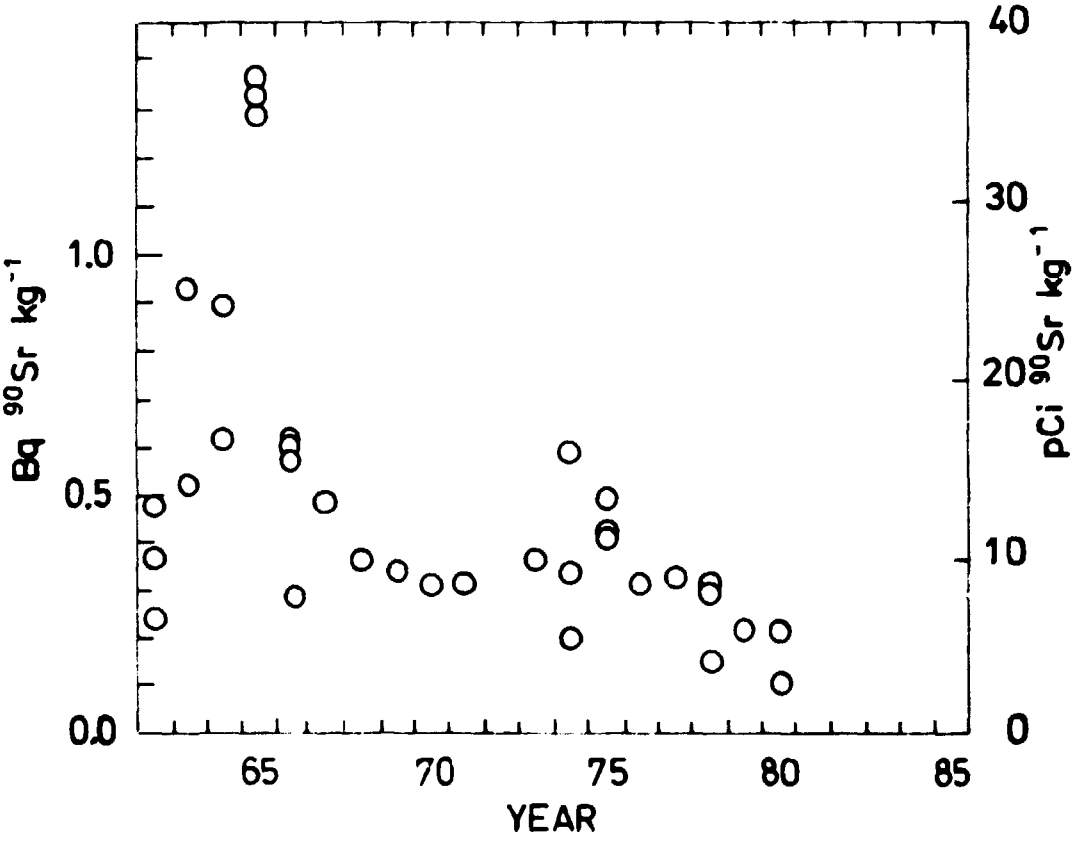

Fig. 2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1980.

2.7.5. Bread

As in previous years[1], rye bread and white bread were collected at Thorshavn in June and December. The mean levels in white bread were 0.12 Bq ^{90}Sr kg^{-1} and 0.10 Bq ^{137}Cs kg^{-1}. The rye bread collected in 1980 contained on the average 0.32 Bq ^{90}Sr kg^{-1} and 0.18 Bq ^{137}Cs kg^{-1}, i.e. the bread levels were half to two thirds of the 1979 levels.

Table 2.7.5. Strontium-90 and Cesium-137 in Faroese bread in 1980

Month	Sort	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
June	White bread	0.11	93	0.11	83
June	Rye bread	0.37	230	0.21	99
Dec	White bread	0.14	480	0.086	57
Dec	Rye bread	0.26	150	0.15	70

The ^{137}Cs and ^{90}Sr levels in Faroese bread were generally lower than the corresponding Danish[2].

2.7.6. Eggs

Eggs were collected from Thorshavn in June and December 1980. Table 2.7.6 shows the results. The mean levels of hens eggs were 0.018 Bq ^{90}Sr kg^{-1} (35 Bq (kg Ca)$^{-1}$ and 0.064 Bq ^{137}Cs kg^{-1}.

Table 2.7.6. Strontium-90 and Cesium-137 in hens eggs from the Faroes in 1980

Month	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
June	0.022	42	0.090	77
Dec	0.015	28	0.039	31

2.8. Humans

2.8.1. Strontium-90 in human bone

In 1980 seven human bone samples representing 9 individuals from Dronning Alexandrine's Hospital in Thorshavn were analysed. Table 2.8.1 shows the results.

The mean level in bone of newborn infants was 38 Bq ^{90}Sr (kg Ca)$^{-1}$ (1.0 pCi ^{90}Sr (g Ca)$^{-1}$).

The adult bone samples were all femur and the mean content was 43 Bq ^{90}Sr (kg Ca)$^{-1}$ (1.2 pCi ^{90}Sr (g Ca)$^{-1}$).

The bone levels in 1980 were in general lower than those observed in 1979.

Table 2.8.1. Strontium-90 in human bone collected in the Faroes in 1980

Age	Bone type		Sex	Bq ^{90}Sr (kg Ca)$^{-1}$	S.U.
0	Vertebrae	2 individuals	M	22	0.60
0	Vertebrae	2 individuals	F	54	1.46
92	Femur	Amputation	M	49	1.32
67	Femur	- " -	F	50	1.35
72	Femur	- " -	F	48	1.31
72	Femur	- " -	F	51	1.37
91	Femur	- " -	F	15	0.40

3. ESTIMATE OF THE MEAN CONTENTS OF ^{90}Sr AND ^{137}Cs IN THE HUMAN DIET

3.1. Annual quantities

The annual quantities are still based on the estimate made by Professor E. Hoff-Jørgensen, Ph.D., in 1962[1] assuming a daily per caput intake of approximately 3000 calories (12.6 MJ).

3.2. Milk and cream

75% of the milk consumed in the Faroes is assumed to be of local origin, and 25% comes from Denmark. Hence the ^{90}Sr content in milk consumed in the Faroes in 1980 was $1.2 \cdot (0.75 \cdot 0.28 + 0.25 \cdot 0.105) = 0.284$ Bq ^{90}Sr kg^{-1}, and the ^{137}Cs content was $0.75 \cdot 4.3 + 0.25 \cdot 0.111 = 3.25$ Bq ^{137}Cs kg^{-1} (cf. 2.3 and ref. 2). 1 kg milk contains 1.2 g Ca.

3.3. Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 2 were used: 0.90 Bq ^{90}Sr kg^{-1} and 0.08 Bq ^{137}Cs kg^{-1}.

3.4. Grain products

As most grain products are imported from Denmark, the Danish figures for 1980[2] were used in the calculation of the Faroese levels. The mean daily consumption of grain products in the Faroes is, as in Denmark, 80 g rye flour, 120 g wheat flour, and 20 g grits. Hence the mean concentration of ^{90}Sr in grain products consumed in the Faroes in 1980 is 0.38 Bq ^{90}Sr kg^{-1} and 0.24 Bq ^{137}Cs kg^{-1}.

3.5. Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The values from Table 2.7.4 were used, i.e. 0.15 Bq ^{90}Sr kg^{-1} and 3.54 Bq ^{137}Cs kg^{-1}.

3.6. Other vegetables and fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures from 1980[2)] were used. Thus the mean contents in vegetables other than potatoes were 0.34 Bq ^{90}Sr kg^{-1} and 0.084 Bq ^{137}Cs kg^{-1}, and the mean contents in fruit were 0.05 Bq ^{90}Sr kg^{-1} and 0.03 Bq ^{137}Cs kg^{-1}.

3.7. Meat and eggs

Meat and egg consumption in the Faroes is estimated to consist of 50% locally produced mutton (or lamb), 25% local whale meat, and 25% sea birds and eggs.

The mutton contained 0.27 Bq ^{90}Sr kg^{-1} and 48 Bq ^{137}Cs kg^{-1} (cf. 2.4). Whale meat from 1980 contained 0.04 Bq ^{90}Sr kg^{-1} and 0.19 Bq ^{137}Cs kg^{-1}, sea birds from 1979 and eggs from 1980 (cf. 2.7.6): 0.007 Bq ^{90}Sr kg^{-1} and 0.018 Bq ^{90}Sr kg^{-1}, and 0.27 and 0.064 Bq ^{137}Cs kg^{-1} respectively.

Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1980 to be

$$0.50 \cdot 0.27 + 0.25 \cdot 0.04 + 0.25 \cdot \left(\frac{0.007+0.018}{2}\right) = 0.15 \text{ Bq } ^{90}Sr \text{ } kg^{-1}$$

and the ^{137}Cs content to be

$$0.50 \cdot 48 + 0.25 \cdot 0.19 + 0.25 \cdot \left(\frac{0.27+0.064}{2}\right) = 24.1 \text{ Bq } ^{137}Cs \text{ } kg^{-1}.$$

3.8. Fish

All fish consumed in the Faroes is of local origin, and the mean contents in fish, obtained from subsection 2.5, were 0.0135 Bq ^{90}Sr kg^{-1} and 0.27 Bq ^{137}Cs kg^{-1}.

3.9. Coffee and tea

The Danish figures for 1980[2] were used, i.e. 0.66 Bq ^{90}Sr kg^{-1} and 2.21 Bq ^{137}Cs kg^{-1}.

3.10. Drinking water

The mean value found in Table 2.6.1 was used, i.e. 0.0053 Bq ^{90}Sr kg^{-1}. The ^{137}Cs content was estimated to be approximately one fourth (the ratio found in New York tap water in 1964[4]) of the ^{90}Sr content, i.e. 0.001 Bq ^{137}Cs kg^{-1}.

Tables 3.1 and 3.2 show the diet estimates of ^{90}Sr and ^{137}Cs respectively.

Table 3.1. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1980

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	146	0.284	41.46	36.3
Cheese	7.3	0.90	6.57	5.8
Grain products	80	0.38	30.40	26.6
Potatoes	91	0.15	13.65	11.9
Vegetables	20	0.34	6.80	5.9
Fruit	18	0.05	0.90	0.8
Meat and eggs	37	0.15	5.55	4.9
Fish	91	0.0135	1.23	1.1
Coffee and tea	7.3	0.66	4.82	4.2
Drinking water	548	0.0053	2.90	2.5
Total			114.28	

The mean annual calcium intake is estimated to be 0.6 kg (approx. 200-250 g of creta praeparata). Hence the ratio: Bq ^{90}Sr $(kg\ Ca)^{-1}$ in total Faroese diet was 190 (5.14 pCi ^{90}Sr $(g\ Ca)^{-1}$).

Table 3.2. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1980

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	146	3.25	474.5	27.1
Cheese	7.3	0.08	0.6	0
Grain products	80	0.24	19.2	1.1
Potatoes	91	3.54	322.1	18.4
Vegetables	20	0.084	1.7	0.1
Fruit	18	0.03	0.5	0
Meat and eggs	37	24.1	891.7	50.9
Fish	91	0.27	24.6	1.4
Coffee and tea	7.3	2.21	16.1	0.9
Drinking water	548	0.001	0.5	0
Total			1751.5	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs $(kg\ K)^{-1}$ becomes 1460 (39.4 pCi ^{137}Cs $(g\ K)^{-1}$).

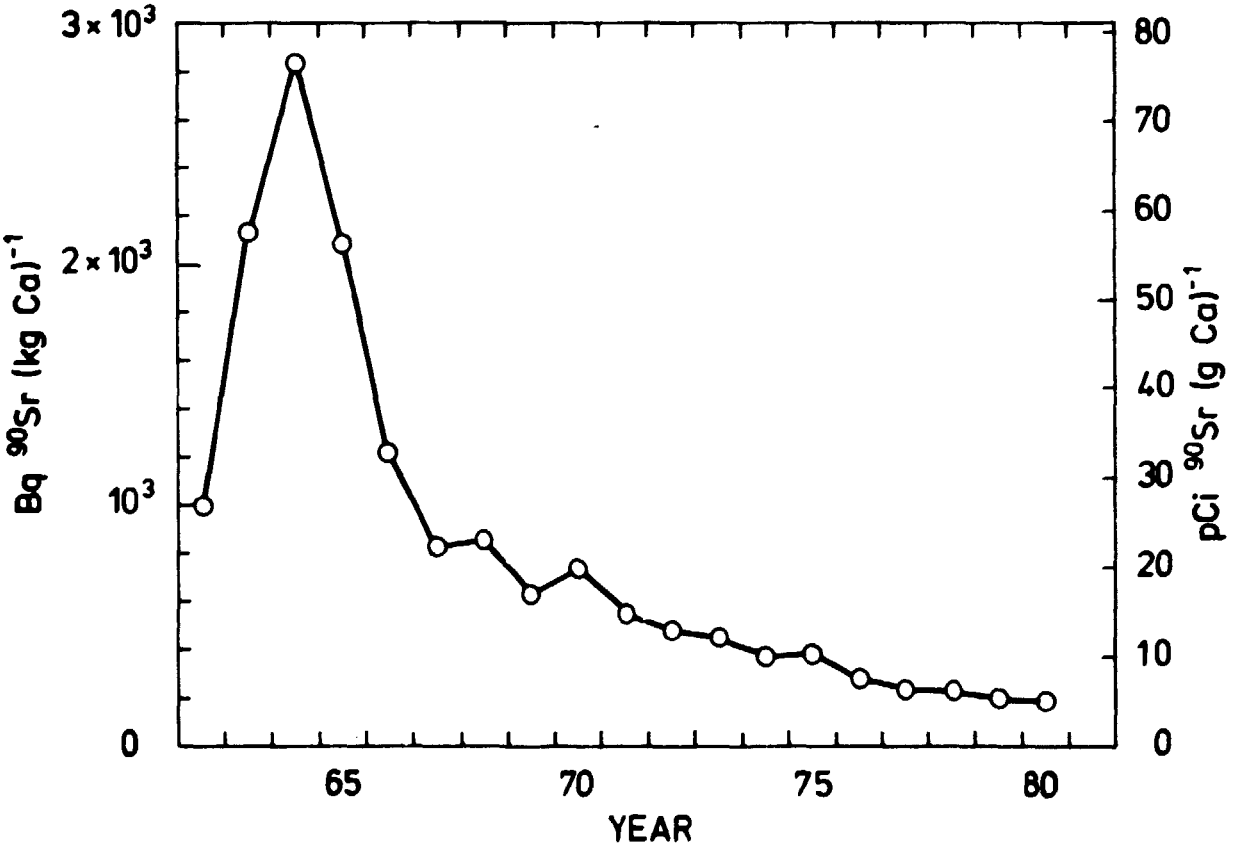

Fig. 3.1. Strontium-90 in Faroese diet, 1962-1980.

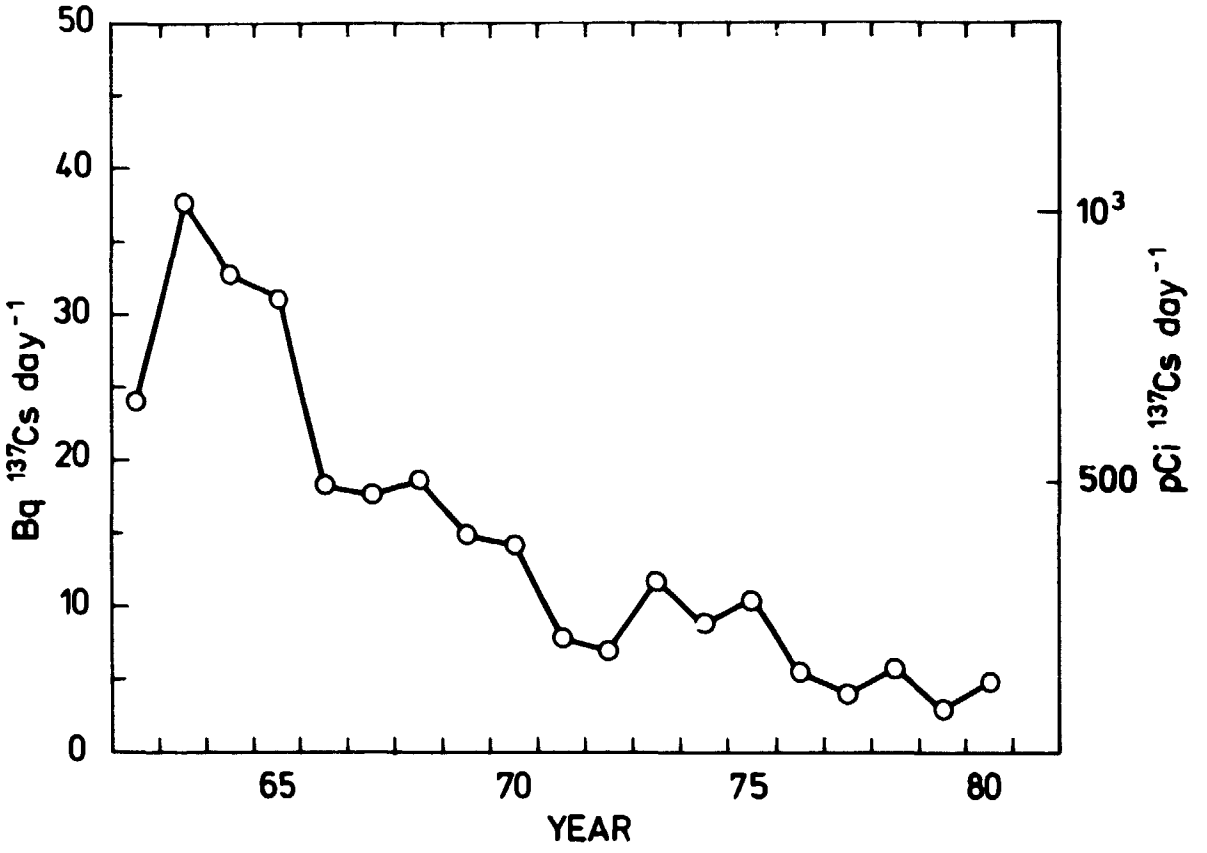

Fig. 3.2. Cesium-137 in Faroese diet, 1962-1980.

3.11. Discussion

Figure 3 shows the Faroese diet levels since 1962.

The 1980 ^{90}Sr level in the total diet was nearly equal to the 1979 concentration, and the ^{137}Cs level was 68% higher than that observed in 1979.

The main contributors to the ^{90}Sr content in the Faroese diet were milk products, cereals and potatoes, which together accounted for approximately 81% of the total ^{90}Sr content in the diet in 1980. As regards ^{137}Cs, milk products, meat (lamb) and potatoes were the most important contributors. In 1980, 96% of the total ^{137}Cs content in the diet originated from these products.

The Faroese mean diet contained 1.3 times as much ^{90}Sr and approximately 12 times as much ^{137}Cs as the Danish diet in 1980[2].

As earlier[1] mentioned, the year-to-year variations in the ^{137}Cs estimates for Faroese diet are markedly influenced by the mutton and potatoe samples obtained for analysis (cf. Table 2.4.1).

4. CONCLUSION

4.1.

The ^{90}Sr fallout rate in the Faroes in 1980 was approximately 12 Bq ^{90}Sr m^{-2} (0.33 mCi km^{-2}). The accumulated fallout by the end of 1980 was estimated at approximately 3700 Bq ^{90}Sr m^{-2} (100 mCi km^{-2}) (the mean at Thorshavn and Klaksvig).

4.2.

The mean level of ^{90}Sr in Faroese milk was 280 Bq (kg Ca)$^{-1}$ (7.7 pCi (g Ca)$^{-1}$). The ^{137}Cs concentration was 4300 Bq ^{137}Cs m^{-3} (117 pCi l^{-1}).

Mutton contained 0.22 Bq ^{90}Sr kg^{-1} (5.9 pCi kg^{-1}) and 48 Bq ^{137}Cs kg^{-1} (1.3 nCi kg^{-1}). Fish showed a mean level of 0.27 Bq ^{137}Cs kg^{-1} (7.3 pCi kg^{-1}).

The mean content of ^{90}Sr in drinking water was 5.3 Bq m^{-3} (0.14 pCi l^{-1}).

The mean daily per caput intakes resulting from the Faroese diet in 1980 were estimated at 0.31 Bq ^{90}Sr (8.5 pCi d^{-1}) and 4.8 Bq ^{137}Cs (130 pCi d^{-1}).

4.3.

From the measurements on Faroese bones, the Faroese bone level in 1980 was estimated at 50 Bq ^{90}Sr (kg Ca)$^{-1}$ (1.3 pCi (g Ca)$^{-1}$).

The mean content of ^{137}Cs in the Faroese adult was estimated at approximately 4000 Bq ^{137}Cs (kg K)$^{-1}$ (110 pCi (g K)$^{-1}$). This estimate is based on the diet estimate.

ACKNOWLEDGEMENTS

The authors wish to thank Miss Anna Holm Petersen, Mrs. Jytte Clausen, Mrs. Else Sørensen, Mrs. Anna Madsen and Mrs. Helle Porsdal for their conscientious performance of the analyses.

Our special thanks are due to the staff of the pharmacy "Tjaldur" in Thorshavn and to all other persons in the Faroes who have contributed by collecting samples.

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APPENDIX A

The models used for the predictions shown in Table A were based on data collected 1962-1976[6]. It appears that in most cases there was no significant difference between the observed and predicted values; however, in the case of ^{90}Sr in milk, the prediction model overestimated the level as it did in the case of ^{137}Cs in milk from Tværå.

Table A. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1980

Sample	Unit	Observed ±1 S.E.	Number of samples	Predicted	Obs./pre. ±1 S.E.	Model in ref. 6
Drinking water, Thorshavn	Bq ^{90}Sr m^{-3}	9.3 ±1.1	2	12.1	0.77±0.09	C.1.4.1 No. 9
- " - , Klaksvig	- " -	2.0 ±0.5	2	4.0	0.50±0.09	- " - No. 10
- " - , Tvmrå	- " -	4.6 ±1.1	2	4.1	1.12±0.27	- " - No. 11
Sea water	- " -	2.3	1	2.5	0.92	C.1.5.1 No. 3
Rye bread	Bq ^{90}Sr kg^{-1}	0.32 ±0.05	2	0.38	0.83±0.13	C.2.3.1 No. 6
White bread	- " -	0.125±0.015	2	0.135	0.93±0.11	- " - No. 7
Rye bread	Bq ^{137}Cs kg^{-1}	0.18 ±0.03	2	0.25	0.72±0.12	- " - No. 8
White bread	- " -	0.10 ±0.015	2	0.14	0.72±0.11	- " - No. 9
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	5900	1	7700	0.77	C.2.4.1 No. 4
- " -	Bq ^{137}Cs (kg K)$^{-1}$	1290 ±0	2	1280	1.01±0	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.15 ±0.06	2	0.24	0.62±0.24	C.2.5.1 No. 11
- " -	Bq ^{137}Cs kg^{-1}	3.54 ±1.00	3	7.49	0.47±0.13	C.2.5.3 No. 8
Brown algae	Bq ^{90}Sr (kg Ca)$^{-1}$	71	1	123	0.58	C.2.7.1 No. 5
Milk (May 80-April 81)	- " -	270 ±11	36	437	0.61±0.03	C.3.3.1 No. 1
Milk (May 80-April 81) Thorshavn	Bq ^{137}Cs m^{-3}	2900 ±300	12	2100	1.37±0.16	C.3.3.2 No. 7
Milk (May 80-April 81) Klaksvig	- " -	4400 ±400	12	3700	1.19±0.12	- " - No. 9
Milk (May 80-April 81) Tvmrå	- " -	6200 ±300	12	11000	0.56±0.04	- " - No. 11
Mutton	Bq ^{90}Sr (kg Ca)$^{-1}$	2200 ±770	2	2200	1.00±0.35	C.3.4.1 No. 5
- " -	Bq ^{137}Cs (kg K)$^{-1}$	18000 ±17000	2	5900	3.06±2.89	C.3.4.2 No. 5
Sheep bone	Bq ^{90}Sr (kg Ca)$^{-1}$	2500 ±1460	2	2900	0.85±0.50	C.3.4.3 No. 1
Cod fish	- " -	127 ±33	10	33	3.84±1.0	C.3.5.1 No. 3
- " -	Bq ^{137}Cs kg^{-1}	0.27 ±0.02	10	0.25	1.08±0.08	C.3.5.2 No. 2
Whale	Bq ^{90}Sr kg^{-1}	0.04	1	0.016	2.64	C.3.6.1 No. 3
- " -	Bq ^{137}Cs kg^{-1}	0.19	1	0.49	0.39	C.3.6.2 No. 2
Newborn bone	Bq ^{90}Sr (kg Ca)$^{-1}$	38 ±16	2	8.8	4.32±1.82	C.4.3.1 No. 15

APPENDIX B

Sea water and algae from West Norway

In 1980, Gordon Christensen, of the Institute of Energy Technology, and T. Bertelsen, of the Norwegian Institute of Radiation Hygiene, sampled Fucus vesiculosus and Ascophyllum nodosum along the entire Norwegian coastline.

Risø participated at two of the Norwegian locations, Bud and Vågsøy, and made supplementary samplings there (cf. Figs. B.1 and B.2 and Tables B.1 and B.2).

The radiochemical separation of cesium from sea water sample No. 1 (200 l) was performed in the field by co-precipitation with ammonium-molybdo-phosphate (AMP) without a yield determination, whereas sample No. 4 (45 l) was processed in the laboratory with an added ^{134}Cs-spike.

The algal vegetation showed a distinct zonation due to the tides. Pelvetia canaliculata is water covered only a few hours daily followed by Fucus spiralis, Fucus vesiculosus, and Ascophyllum nodosum. Fucus serratus is normally always water covered and Laminaria digitata was sampled even lower.

In addition to the radionuclides in Table B.2, the samples are also being analysed for $^{239,240}Pu$, ^{238}Pu, and ^{241}Am.

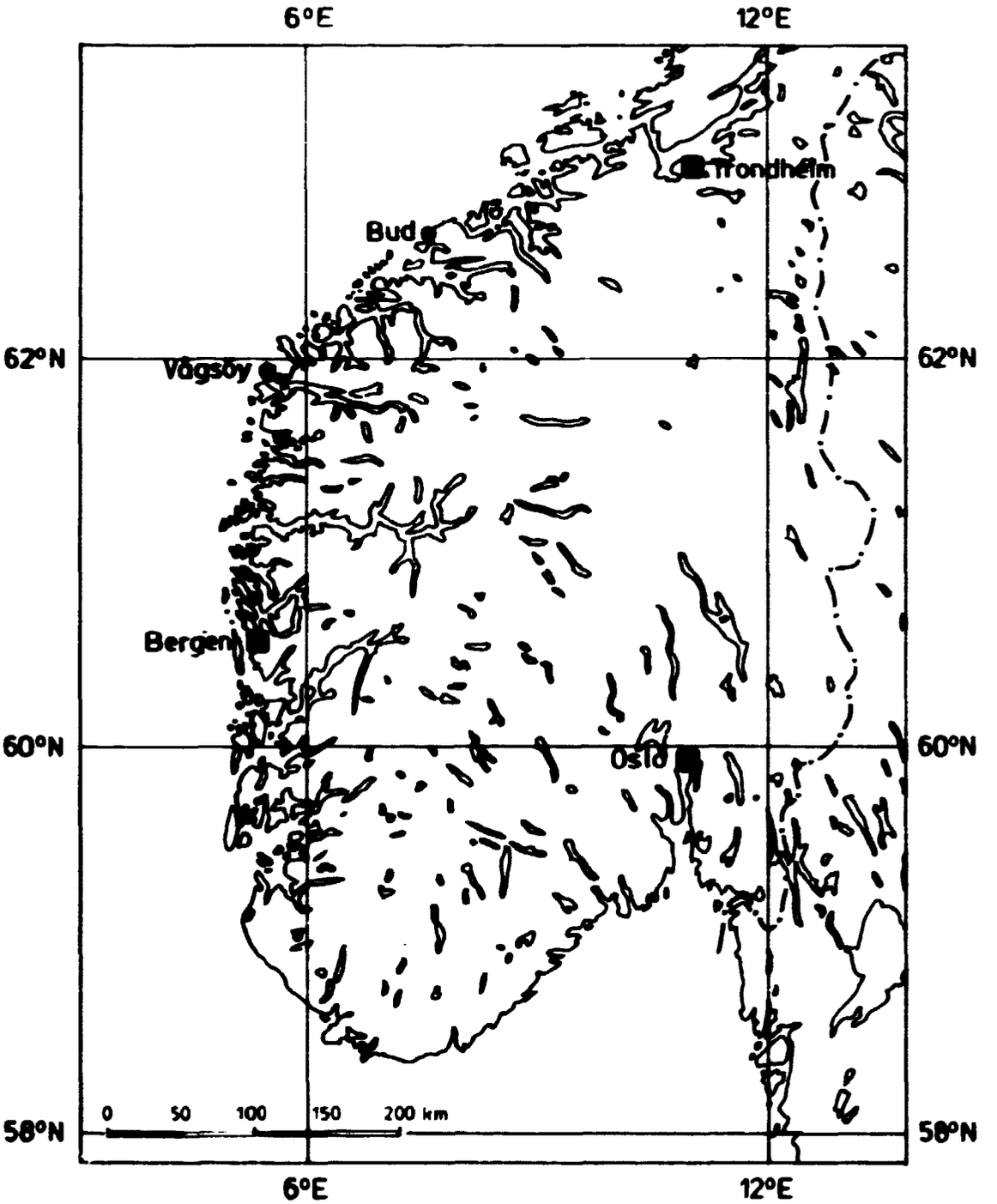

Fig. B.1. Sampling locations in West-Norway, Bud and Vågsøy, 1980.

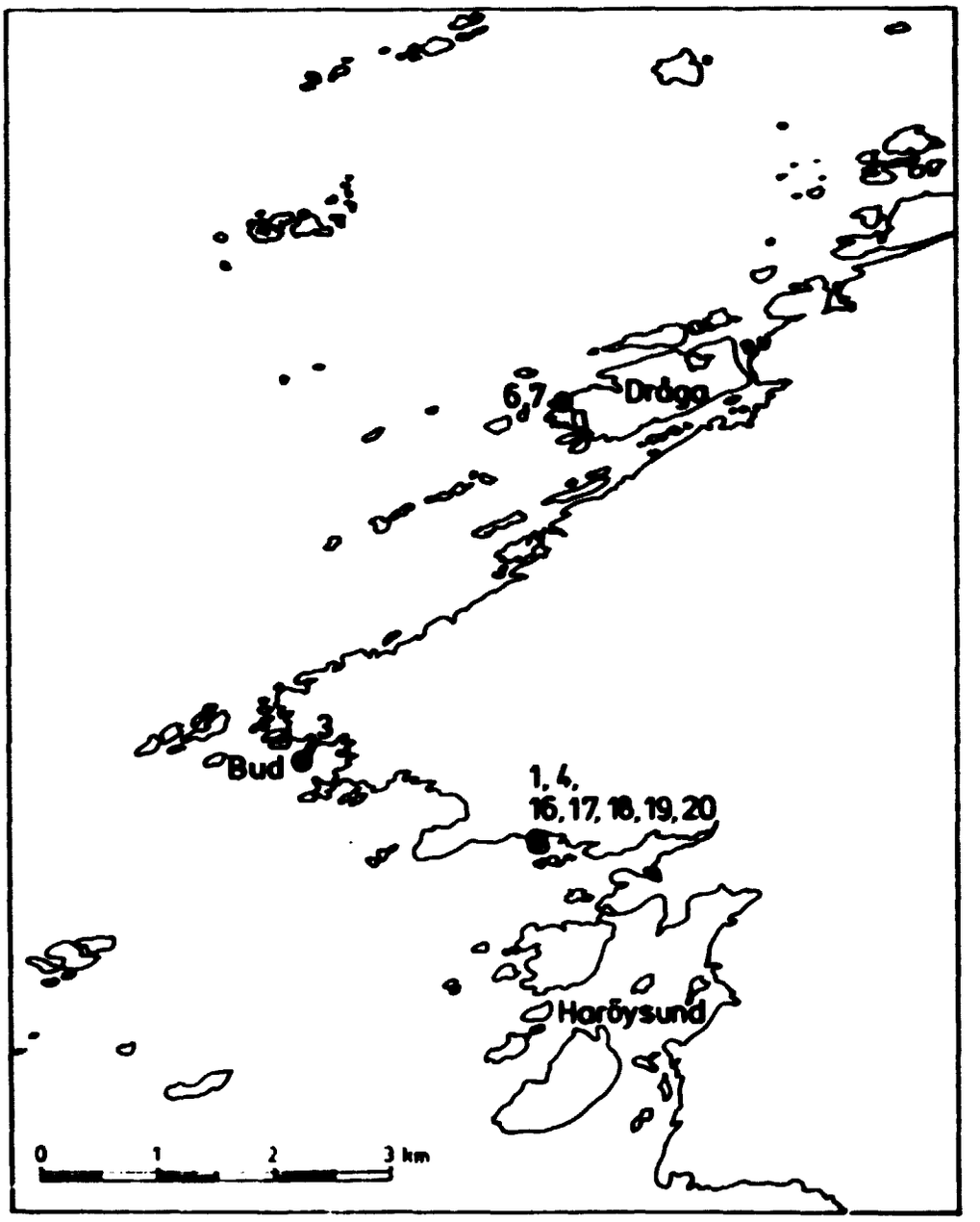

Fig. B.2. Sampling locations in the Bud area, West-Norway, 1980. Sample numbers are indicated.

Table B.1. Cesium-137, Cesium-134 and Strontium-90 in sea water collected in Bud, Norway, September 2-3, 1980 (cf. Figs. B.1 and B.2)

Sample number	Bq ^{137}Cs m^{-3}	Bq ^{134}Cs m^{-3}	Bq ^{90}Sr m^{-3}	Salinity o/oo
1	65	3.8	-	-
4	64	Spilled	29	25.2

Table B.2. Radionuclides in sea plants collected in Norway, 1980 (cf. Figs. B.1 and B.2)

Location	Sample number	Date	Weight fresh/dry	Species	Bq kg^{-1} fresh				Bq (kg Ca)$^{-1}$
					^{137}Cs	^{134}Cs	^{60}Co	^{90}Sr	^{90}Sr
Bud	16	4/9	2.56	Pelvetia canaliculata	2.0			0.150	280
"	17	"	3.62	Fucus spiralis	3.2			0.182	176
"	18	"	2.91	Fucus vesiculosus	3.3			0.106	230
"	19	"	2.98	Ascophyllum nodosum	2.6	0.127	0.06 A	0.050	160
"	20	"	3.83	Fucus serratus	2.7			0.130	200
"	7	3/9	2.96	Pelvetia canaliculata	2.6			0.122	230
"	6	"	2.95	Fucus vesiculosus	3.0			0.137	280
"	3	"	5.60	Laminaria digitata	3.1			0.120	220
Vågsøy		5/9	3.29	Fucus vesiculosus	3.9	0.180	0.112	0.165	310

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ISBN 87-550-0778-3
ISSN 0106-2840